ORAL TESTIMONY
OF
DR. STEVEN E. KOONIN
UNDER SECRETARY FOR SCIENCE
U.S. DEPARTMENT OF ENERGY

December 10, 2009

Section 1 - Background

Electricity is an important and growing form of energy in our society. For the residential and commercial energy consumer electricity represents the cleanest and most convenient form of energy available, and over the past 40 years the market penetration of electricity has increased significantly when compared to other forms of energy[1].

Challenges accompanying the generation and consumption of electricity begin with the significant variation of consumer demand that exists on timescales ranging from diurnal to seasonal. Additionally, unlike other forms of energy that can be easily stored, electricity is uniquely perishable in that unused electrical current cannot be set aside for use at some later time. In combination these two characteristics lead to variable demand on generation, which in turn results in underutilized assets across the grid. Without energy storage, generation and transmission infrastructure is designed to meet peak power instead of average energy demands, resulting in a

[1] EIA Energy Perspectives 2008 – Figures 8 & 9, http://www.eia.doe.gov/emeu/aer/ep/ep_frame.html

design paradigm where the system is used to only about 40% capacity[2] yet requires continued deployment of additional resources[3].

A broad deployment of energy storage technologies would allow for more efficient utilization of our current infrastructure. Functions from short duration to 8 hours in length – including frequency regulation, peak shaving, diurnal matching, and regional balancing – could all be provided by grid integrated storage. Energy benefits would range from reducing losses[4] to improved power quality, while economic benefits would result from increased capacity factors and deferred capital investment[5]. Furthermore, as we strive to incorporate into our national energy supply significant quantities of wind and solar energy, the availability of which is uncertain at any given time, storage will enable more complete exploitation of these resources.

Section 2 – Storage Technologies

Various methods exist to store energy, the simplest and most reversible of which involves moving water between two different elevations. A challenge for pumped hydro storage is that energy density is limited by gravity – even a cubic foot containing 7.5 gallons of water and weighing 62 pounds contains only 0.007 kWh of energy if elevated 300 feet[6]. The limited availability of suitable geography for

---

[2] Electricity Advisory Committee report – *Bottling Electricity: Storage as a Strategic Tool…* (Dec. '08, page 4)
[3] AEO 2009 projects 259 GW new generation required by 2030 - http://www.eia.doe.gov/oiaf/aeo/electricity.html
[4] Because T&D losses are nonlinear, diurnal peak shaving reduces T&D losses (EAC report, Dec. '08, page 12)
[5] Lowering peak power requirements allows for deferred infrastructure and capacity investments.
[6] $PE = mgh$; $28.4\text{kg} * 9.81\text{m/s}^2 * 91.44\text{m} = 25.4\text{KJ} = 7\text{ Wh}$

new pumped hydro storage facilities also limits additional deployment opportunities.

Another form of mechanical storage is compressed air, for which it appears appropriate geology may exist across much of the nation[7]. Although compressed air technology has been demonstrated for decades[8], physics means that a cubic foot of air compressed to 2,000 psi still contains only 0.2 kWh of energy[9]. Batteries can achieve significantly higher energy densities than their mechanical counterparts, potentially storing 20-30 kWh/ft^3 for the most advanced lithium-ion technologies[10], but energy densities of that level come at costs which can be orders of magnitude higher than those for pumped hydro or compressed air.

Comparing these storage technologies with the energy contained in the chemistry of conventional fuel sources reveals the challenge in front of us. A cubic foot of Methane at 1 atmosphere contains 1 kilowatt-hour worth of energy[11], costs just a penny[12], and weighs essentially nothing. Of course, the non-reversible nature of chemical energy means that despite their challenges and high cost, storage technologies hold significant value from both system efficiency and environmental perspectives.

---

[7] Succar and Williams. *Compressed Air Energy Storage: Theory, Resources, And Applications for Wind Power*. Princeton Environmental Institute (April 2008).

[8] Two plans world-wide in Germany (1978) and Alabama (1991).

[9] Mil-Std-1522A states that 1 ft^3 pressurized at 2000 psi contains 543,111 ft-lbs energy. Energy value confirmed by $E=[p_1V/(y-1)][1-(p_2/p_1)^{(y-1)/y}]$, where p_1=test pressure (atm), p_2=1 (atmospheric pressure), V=volume (L), y=1.4 (for nitrogen).

[10] Evaluation of Emerging Battery Technologies for Plug-in Hybrid Vehicles, EPRI Report #1019474, August 2009.

[11] 39 MJ/m^3 = 3.6 MJ/ft^3 = 1006 Wh/ft^3

[12] A wholesale price of $10 per 1,000 cubic feet Methane yields a cost of 1 penny per cubic foot.

Section 3 – Actions

The Department of Energy is pursuing deployment of current energy storage technologies as well as the science behind the next generation of storage solutions. Through the Recovery Act, the Department is funding energy storage demonstrations that encompass the complete range of technologies and scales. From a single battery demonstration project in Pennsylvania to a 300 MW compressed air project in California; these projects will generate a significant body of knowledge that will aid future storage deployment efforts.

Finally, the basic research into physical and chemical properties of electrical energy storage devices currently funded by the Department holds significant promise for next generation storage technologies. Synthesis of novel nanoscale materials with architectures tailored for specific electrochemical performance; characterization of materials and dynamic chemical processes at the atomic and molecular level; and simulation and prediction of structural and functional relationships using computational tools are all now possible. With this knowledge we are working to develop new concepts in materials design that will enable production of low cost storage devices that are capable of higher energy densities, cycle lifetimes, and reliability.